Quarterly Progress Report #6

For the project entitled:

Field Evaluation of the Performance of Three Concrete Bridge Decks on Montana Route 243

Reporting Period: April 1, 2003 – June 30, 2003
(*Quarter 4, State Fiscal Year 2003*)

Summary of Expenditures

The table below summarizes the expenditures on this project through June 30, 2003. Expenditures during this quarter were $70,490.48, with total expenditures through June 30, 2003 equaling $211,947.32.

Budget Category	Spent through 12/31/02	Spent This Quarter	Total Spent
Salaries	$48,969.69	$31,192.15	$80,161.84
Benefits	$7,834.80	$4,904.94	$12,739.74
In-State Travel	$665.19	$7,731.20	$8,396.39
Expendable Supplies	$2,810.54	$12,959.20	$15,769.74
Tuition	$21,120.50	$4,100.00	$25,220.50
Reporting	$0.00	$0.00	$0.00
MDT Direct Costs	$81,400.72	$60,887.49	$142,288.21
Overhead	$12,056.12	$9,602.99	$21,659.11
MDT Share	$93,456.84	$70,490.48	$163,947.32
WTI Share (Equipment and Out-of-State Travel)	$48,000.00	$0.00	$48,000.00
Total	**$141,456.84**	**$70,490.48**	**$211,947.32**

Task A: Project Management

The majority of the activity related to project management focused on ensuring that research activities harmonized efficiently with scheduled construction events. Related activities included:

- delivery and installation of instrumented reinforcement,
- installation of embedded and vibrating wire gages,
- running cabling and calibrating test equipment,
- documenting the final locations of the gages,
- clearly marking instrumented locations with flags,
- pouring the bridge decks,
- collecting concrete samples for future testing, and
- stripping the lower deck forms and installing plumbing.

Each of these items will be discussed in more detail throughout the remainder of the report.

During the construction phase, communication generally occurred between Eli Cuelho and Jim Wickens (Project Manager – Sletten Construction), Jason Plouffe (Deck Construction Supervisor – Sletten Construction), Art Harding (Iron Worker – Sletten Construction), Larry Greufe (Project Manager – MDT), and Craig Abernathy (Research Project Manager – MDT).

Eli Cuelho, Jerry Stephens, Peter Smolenski (Graduate student) and Jay Ling (Undergraduate student) of WTI/MSU attended a post-construction meeting in Helena on June 23rd. The motivation for the meeting was to inform the technical panel about the various research tasks that had been accomplished since the beginning of the project. Eli Cuelho gave a presentation that followed a chronologic summary the research activities.

Action Items for next quarter:

- Coordinate with MDT and Sletten Construction to set up and conduct live load tests

Task B: Conduct Literature Review

The primary literature review for this project has been completed. Nonetheless, the time frame for this project is quite long, so information will continue to be collected throughout its duration. During this quarter, significant literature was collected regarding live load testing of bridge structures. Knowledge gained during this search will help finalize the live load tests scheduled as part of this project.

Action Items for next quarter:

- Continue collecting relevant literature
- Write up the literature review for use in future documentation

Task C: Develop Instrumentation Plan and Assemble Data Acquisition System

Determine Gage Locations

A final draft of the report documenting the process used to select the gage locations in each deck was completed. Illustrations in this document were used to install the instrumented reinforcement, embedded strain gages and vibrating wire gages in the reinforcing cage prior to placing the bridge deck concrete. Information in the instrumentation plan will be summarized and included in the interim project report.

Purchase and Assemble Weather Station

A database was finalized to store the data received from the remote weather station. This database makes it possible to query for specific data making the analysis more efficient. Weather data will interface with strain data collected from the bridges to help characterize environmental effects on the behavior of the structures.

Purchase and Assemble Bridge Monitoring Data Acquisition System

During this quarter, work supporting the bridge monitoring data acquisition system generally focused on:

- fabricating the strain gage circuitry,
- completing the data acquisition computer program,
- installing the data acquisition system on the bridge,
- calibrating all gages,
- installing power and communication systems,
- collecting data during and after concrete was placed in the bridge decks, and
- preparing the data acquisition system for live load testing.

During the previous quarter, multiple tests were conducted to evaluate the durability and accuracy of the circuitry used with the bonded strain gages. A final circuit design was selected and fabricated based on these tests. This design was configured to accommodate all 42 resistance strain gages in each bridge deck (35 bonded to the reinforcement and 7 gages embedded in the concrete). To do this, seven circuit boards were fabricated for each bridge, each having a enough capacity to accommodate six resistance strain gages (five gages on the reinforcement and one embedded in the concrete).

Each of these boards was connected to a single motherboard. This configuration aided in quick assembly and greater flexibility during the live load tests. The motherboard receives information from each of the peripheral circuit completion boards (“daughterboards”) and routes it either directly or indirectly to the data acquisition computer. Multiplexers are used to increase the capacity of the data acquisition system. A single multiplexer is able to receive 32 separate sensor readings. It acquires data at a slow rate (approximately 1 Hz) by switching through its channels. The information is stored in an array using a single port on the face of the data logger. An advantage of using multiplexers is that it increases the number of available data ports; a disadvantage is that it cannot take data quickly. Figure 1 illustrates the various components housed within each of the data acquisition boxes.

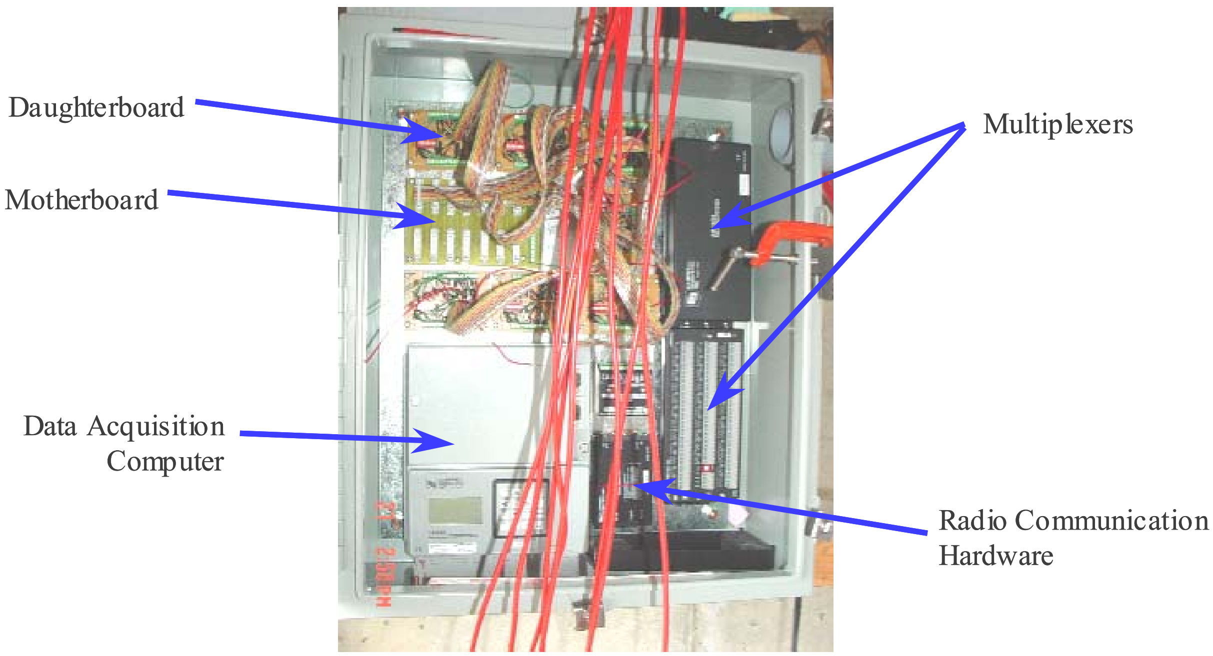

Figure 1: Various Components within A Data Acquisition Box.

The data acquisition system uses computer code to operate. As such, a computer program was written to control data collection activities at the bridge site. Prior to installing the final program on the data acquisition computers, the program was tested at MSU to ensure that it was working properly. In general, the program was written to deliver excitation voltage to each of the sensors at predetermined times, capture each sensor's response and store that information in memory within each of the data acquisition computers. Data collected and stored may then be automatically transferred using a series of antennas linked to an Internet connection.

Once the sensors were installed in the bridge decks and connected to the data acquisition system, they required calibration and/or zeroing. To calibrate the bonded and embedded resistance strain gages an electrically induced strain is simulated using a shunt calibration resistor. A linear relationship between strain and voltage output is determined using this technique. This relationship is used in the data acquisition computer program to automatically convert output voltage to strain. Prior to casting the deck, zero values were collected from the bonded and embedded resistance strain gages. The vibrating wire gages were calibrated by the manufacturer and therefore only required taking an initial reading or "zero point" for the strain value. Calibrating the vibrating wire sensors prior to pouring the deck concrete was impossible since these gages do not provide accurate results prior to being embedded in concrete. Therefore, they were calibrated and zeroed after the pour, when the concrete began to initially harden. Temperatures readings from the vibrating wires did not need to be calibrated or zeroed.

Power to operate the data acquisition equipment at each of the bridges is achieved by using a deep-cell, 12-volt battery charged by a solar panel. The solar panels, as well as the communication antennas, were attached to tall wooden poles near the southeast corner of the bridges. The final locations of these poles may be moved to the west side once the temporary construction detour is removed. At that time, the power and communications cabling will be buried for protection. An additional antenna was also affixed to the radio tower near the weather station atop the Saco Public School to receive and transmit information between WTI and the bridges.

The instrumentation for all three decks has been active since the time they were cast. For approximately ten days, strain and temperature readings from each gage were recorded every ten minutes to capture the rapid changes during construction and curing. Following this period, the interval between readings was lengthened to one hour. Data collection is scheduled to continue in this manner until the live load experiment. After the live load tests, the data acquisition program will be rewritten to capture strains from selected sensors during “large” events. A large event will be defined by setting tolerances for specific gages based on their response during the live load tests.

A general data acquisition plan has been developed to prepare for the live load experiments. During the live load experiment, one bridge will utilize all three data loggers. The current setup of the data acquisition system at each of the bridges does not allow for rapid collection (e.g., 100Hz scan rate) of all of the bonded and embedded strain gages due to limitations associated with the multiplexers. Therefore, by using multiple data acquisition computers simultaneously, the sensors can be directly connected to the data logger face to achieve rapid data collection. The circuit design was configured to accommodate this arrangement with minimal effort. Additionally, a hand-held switch will be used to record the position of the truck as it passes predetermined locations on the deck when conducting the slow live load tests. The data acquisition program will also be modified to include four additional gages from Bridge Diagnostics Incorporated (BDI) that will be temporarily affixed to the bottom of the stringers during the live load tests.

<u>Action Items for Next Quarter:</u>

- Configure computer program and extra hardware for live load experiment
- Determine gages that will trigger future large events
- Install final solar/communication pole after removal of detour

- Complete documentation and wiring diagrams for the final arrangement of the data acquisition system

Task D: Install Instrumentation and Compile As-Built Documentation

Instrumentation Installation

Installation of strain gages to the reinforcing steel concluded this quarter. Completed bars were bundled securely together and transferred to the construction site on April 21st. Installation of the instrumented reinforcement began immediately following delivery. Eli Cuelho was present during placement of all instrumented rebar to ensure they were installed properly and carefully. The embedded resistance strain gages and the vibrating wire strain gages were installed once the reinforcing cage was built. These gages were tied in place using the same plastic-coated wire used to tie the reinforcing cage together. Lead wires were run through predrilled exit ports located in the bottom of the deck. Cabling was bundled together and tied to the underside of reinforcing bars or to the chairs (used to space the top mat of reinforcement from the bottom mat).

Precise coordinates of each instrument location were documented after they were installed, prior to the deck concrete being placed. Once all sensors were in place, small plastic inserts were attached to the sides of the longitudinal formwork to indicate the location of the transverse gage lines. The plastic inserts left a permanent indentation in the concrete when the forms were removed. These indentations will help to exactly locate the gage lines in the future. In addition, longitudinal and transverse measurements were made to document the locations of all the gages. Digital photographs were also taken to record the orientation and layout of each gage.

All gage installations so that the construction workers would know where to exhibit greater care during concrete placement. The flags were constructed using thin dowels tied in the shape of a teepee. They were tied to the reinforcing cage near each gage location using zip ties. Once the concrete was placed and vibrated, the flags were removed by simply pulling them free.

The data acquisition box for each deck was hung temporarily under the bridge near the south bent, and the lead wires from the gages were connected to the data acquisition system after being routed through exit ports in the deck forms. Because water levels were higher than expected, wooden platforms were built to stand on while working on the data acquisition system. In addition, wooden scaffolding was built to facilitate plumbing the wires through conduit for the HPC deck. Figure 2 shows the arrangement of the scaffolding and conduit.

Figure 2: Scaffolding and Conduit Arrangement.

The bottom of the bridge decks need to be deformed before the lead wires can be permanently plumbed in PVC conduit. WTI is coordinating with Sletten Construction to accomplish this work. Care must be taken during the deforming process to ensure that no wires are damaged. At the end of this reporting period, forms had only been removed from the HPC deck, and plumbing of the lead wires on this deck was completed.

As previously mentioned, four additional gages (Intelliducers ™) from Bridge Diagnostics Incorporated (BDI) will be temporarily affixed to the bottom of the stringers during the live load tests. These gages will help characterize the global response of the bridge. They will be removed and attached to each structure as the live load tests are successively conducted on each bridge. A typical BDI gage and its installation is shown in Figure 3.

Figure 3: External Clip Gage from Bridge Diagnostic Incorporated.

Action items for next quarter:

- Create a database for all sensor locations
- Finish plumbing wires into data acquisition boxes
- Attach BDI gages to the bottom of the stringers

Materials Testing

Test specimens were collected from a representative portion of the concrete used to cast the instrumented section of each deck. A summary of the samples collected from each bridge, the conditions under which these samples will be cured, and the tests to which these samples will be subjected is presented in Table 1 through 3 below. Sixteen to eighteen truckloads of concrete (approximately 125 cubic yards) were used to cast each bridge. The instrumented areas of each bridge generally were cast with concrete from the 4th truck through the 8th truck. Rather than sampling from a single truck in the instrumented region of the decks, as was originally proposed, the decision was made at the time of the deck pours to collect samples from three of the trucks from the instrumented region of each deck (samples were actually collected from four trucks for the conventional deck). Samples were taken for determining the compression strength, flexural tensile strength, splitting tensile strength, and shrinkage properties of the concrete. Generally, one truck from each bridge was more heavily sampled than the remaining trucks. These additional samples will be used to characterize the tension and shrinkage properties of the concrete.

Twenty-eight day compression tests were performed on samples from the HPC and Empirical decks. Load and displacement data was collected from each specimen, so that the stress-strain behavior of the concrete can be determined. Similar tests will be performed on specimens from the conventional deck after 28-days has elapsed from the time they were cast. When applicable, average strength values from the 28-day compression tests are shown in Tables 1 and 2.

For all three decks, the specimens to be cured with the decks will be stripped from their molds at the same time that the forms are stripped from the decks (this task is expected to be done the first couple of weeks in July). These specimens presently are being cured in the MDT yard at Saco. They may be moved to the bridge site and stored on the pile caps once all construction is complete. These specimens will be tested as outlined in Tables 1 through 3.

During bridge construction, MDT performed air content tests, conducted slump tests, and collected compression test specimens from the concrete from selected trucks on each bridge. Results of these tests will be included in the project analysis and documentation.

Action Items for Next Quarter

- Test 28-day concrete cylinders from the Conventional bridge deck
- Collect material properties of the reinforcing steel from MDT

Table 1: Concrete Sampling and Testing Matrix – HPC Deck, Cast 5/28/03.

Truck No.	Type of Specimen[a]	Number of Specimens	Curing	Time to be tested	Type of test	Results
H-4	cylinder	1	moist	28 days	compression	49.9 MPa
	cylinder	2	with deck	1st live load	compression	σ – ε curve
	cylinder	2	with deck	1st live load	split-cylinder	
	cylinder	2	with deck	2nd live load	compression	σ – ε curve
	beam	2	with deck	1st live load	bending	
	beam	1	with deck	2nd live load	bending	
	shrink	3	with deck	periodically	shrinkage	
	shrink	3	moist	periodically	shrinkage	
H-6	cylinder	2	moist	28 days	compression	45.6 MPa
	cylinder	2	with deck	1st live load	compression	σ – ε curve
	cylinder	2	with deck	2nd live load	compression	σ – ε curve
	beam	2	with deck	1st live load	bending	
	beam	1	with deck	2nd live load	bending	
H-8	cylinder	1	moist	28 days	compression	43.0 MPa
	cylinder	2	with deck	1st live load	compression	σ – ε curve
	cylinder	2	with deck	2nd live load	compression	σ – ε curve
	beam	1	with deck	1st live load	bending	
	beam	2	with deck	2nd live load	bending	

[a] *cylinder – 152 mm (6 in) diameter by 305 mm (12 in) long cylinder*
beam – 152 mm (6 in) wide by 152 mm (6 in) deep by 508 mm (20 in) long beam
shrink – 76 mm (3 in) wide by 76 mm (3 in) deep by 406 mm (16 in) long beam

Table 2: Concrete Sampling and Testing Matrix – Empirical Deck, Cast 6/02/03.

Truck No.	Type of Specimen[a]	Number of Specimens	Curing	Time to be tested	Type of test	Results
E-5	cylinder	3	moist	28 days	compression	27.7 MPa
	cylinder	3	with deck	1st live load	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	2nd live load	compression	$\sigma - \varepsilon$ curve
	beam	2	with deck	1st live load	bending	
E-7	cylinder	3	moist	28 days	compression	27.5 MPa
	cylinder	3	with deck	1st live load	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	1st live load	split cylinder	
	cylinder	3	with deck	2nd live load	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	2nd live load	split cylinder	
	beam	2	with deck	1st live load	bending	
	beam	2	with deck	2nd live load	bending	
	shrink	3	with deck	periodically	shrinkage	
	shrink	3	moist	periodically	shrinkage	
E-9	cylinder	3	moist	28 days	compression	27.0 MPa
	cylinder	3	with deck	1st live load	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	2nd live load	compression	$\sigma - \varepsilon$ curve
	beam	2	with deck	2nd live load	bending	

[a] *cylinder – 152 mm (6 in) diameter by 305 mm (12 in) long cylinder*
beam – 152 mm (6 in) wide by 152 mm (6 in) deep by 508 mm (20 in) long beam
shrink – 76 mm (3 in) wide by 76 mm (3 in) deep by 406 mm (16 in) long beam

Table 3: Concrete Sampling and Testing Matrix – Conventional Deck, Cast 6/05/03.

Truck No.	Type of Specimen[a]	Number of Specimens	Curing	Time to be tested	Type of test	Results
C-4	cylinder	3	moist	28 days	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	1st live load	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	2nd live load	compression	$\sigma - \varepsilon$ curve
	beam	2	with deck	1st live load	bending	
C-5	cylinder	2	with deck	1st live load	compression	$\sigma - \varepsilon$ curve
	cylinder	2	with deck	2nd live load	compression	$\sigma - \varepsilon$ curve
C-6	cylinder	3	moist	28 days	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	1st live load	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	1st live load	split cylinder	
	cylinder	3	with deck	2nd live load	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	2nd live load	split cylinder	
	beam	2	with deck	1st live load	bending	
	beam	2	with deck	2nd live load	bending	
	shrink	3	with deck	periodically	shrinkage	
	shrink	3	moist	periodically	shrinkage	
C-7	cylinder	3	moist	28 days	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	1st live load	compression	$\sigma - \varepsilon$ curve
	cylinder	3	with deck	2nd live load	compression	$\sigma - \varepsilon$ curve
	beam	2	with deck	2nd live load	bending	

[a] *cylinder – 152 mm (6 in) diameter by 305 mm (12 in) long cylinder*
beam – 152 mm (6 in) wide by 152 mm (6 in) deep by 508 mm (20 in) long beam
shrink – 76 mm (3 in) wide by 76 mm (3 in) deep by 406 mm (16 in) long beam

Task E: Live Load Testing

Live load tests will be conducted on each bridge during the next reporting period. These tests will be conducted after the decks are grooved and sealed and shortly after the bridge approaches have been paved. These tasks are expected to be completed in mid to late July. The vehicle(s) used in these tests will be a 3-axle dump truck. Typical dimensions for a 3-axle dump truck are shown in Figure 4. Note that while the distance between the axles in the tandem is fairly standard (1.3 m), the distance from the front axle to the first axle of the tandem (shown as 4.9 m) is somewhat variable. This variation is relatively unimportant in this test, as it has nominal effect on the maximum local stresses in the deck, which are more influenced by the magnitude of the forces applied by the individual wheels.

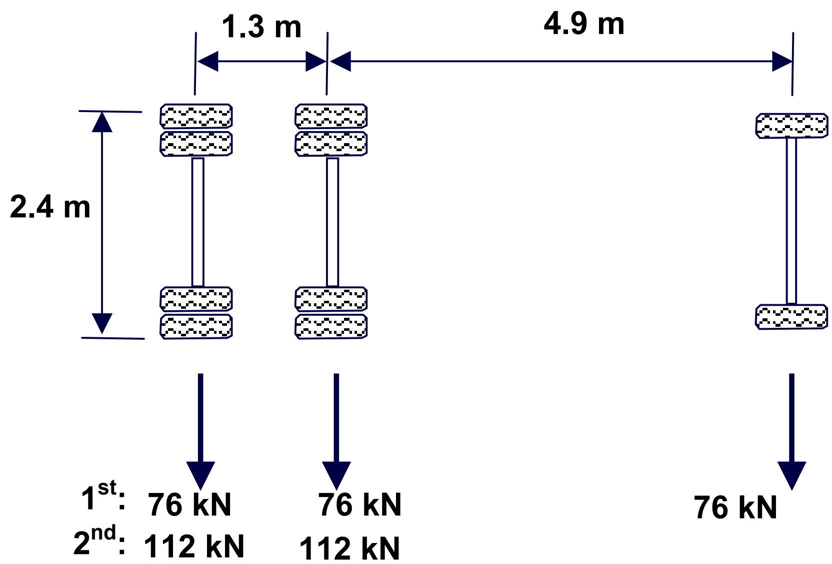

Figure 4: Typical Configuration, 3-Axle Dump Truck.

The first set of weights listed in Figure 4 is approximately the maximum legal weight that can be carried on this vehicle. This is based on the following three considerations:

1. the tandem axle weight is at the maximum allowed for this axle group,
2. the single (steer) axle is at approximately 85 percent of the maximum allowable single-axle weight, and
3. the gross vehicle weight is at the maximum allowed by the bridge formula.

Preliminary analysis of the structural demands generated by this vehicle found that the longitudinal moments (carried by the composite action of the stringers and the deck) are 75 percent of the HL-93 design moment, and that the transverse moments (carried locally by the deck spanning between the stringers) are 60 percent of the design moments. Note that in the case of the deck moments, the design moments were the result of using a 142 kN (32 kip) single axle positioned transversely to generate the highest possible moment in the deck.

In light of the aforementioned calculations, it seems prudent to use a heavier vehicle for the live load testing. In the second set of loads shown in Figure 4, the weight on the rear tandem has been increased to the HL-93 tandem design load of 112 kN per axle (note, however, that the AASHTO bridge code does not appear to require that bridge decks be designed for the HL-93 tandem design load, but is simply used in determining longitudinal design moments). This load generates transverse moments in the deck equal to approximately 90 percent of those from the design load (taken as a 142 kN single axle, as mentioned above). Under the second set of loads shown in Figure 4, the longitudinal moment demand is 4 percent greater than the longitudinal moment generated by the HL-93 design vehicle, and the local transverse moments in the deck are 90 percent of the design moments.

The heavier vehicle is desirable for the live load tests since it pushes the decks closer to their design demands and may better expose reinforcing related differences in behavior between the empirical and conventional decks. It may, however, be difficult to achieve these weights on this vehicle, due to volume constraints and equipment overloading concerns. In reviewing bridge tests conducted by others, one or two cases were found in which heavy 3-axle dump trucks were used, with wheel loads on the order of magnitude of the second set of loads shown in Figure 4. Alternate vehicle configurations were investigated such as grain trucks, farm tractors, etc., and they were found to offer little advantage over 3-axle dump trucks with respect to maximizing demands on the deck.

In light of this situation, it is suggested that the bridges be tested using as heavy a 3-axle dump truck as the MDT Bridge Bureau and truck operator are comfortable with (but not to exceed the GVW and axle weights shown in the second set of loads in Figure 4). MSU will directly discuss test vehicle requirements (axle weights and test schedule) with MDT personnel in the Wolf Point maintenance yard. It is anticipated that a truck will have to be continuously on site throughout the duration of the live load tests, which are expected to take 3 to 5 days to complete. Some of the tests proposed for each bridge require two trucks, traveling side-by-side across the bridge. A second truck will be required for approximately one hour per day to run these tests.

In finalizing plans for the live load tests, the decision was made to conduct tests at two speeds (compared to the 3 speeds mentioned in the last progress report). Up to ten runs will be done on each bridge at slow speed (essentially static) using a single truck. Each run will be done at a different transverse position across the bridge as shown in Figure 5. One or two of these runs may be repeated, to determine if the properties of the decks are altered by the load events themselves. Data will be continuously recorded during all the test runs (at a sampling rate of 100 to 200 Hz). Truck position will be recorded at regularly spaced intervals during each run, coincident with the strain data. One to one and one-half meter intervals will be used in the vicinity of the instrumented sections of the deck, and up to three meter intervals may be used at locations remote from the instrumentation. Both the longitudinal truck paths and the transverse position indicators will be identified on the decks using painted lines (two inch width, colors muted and distinct from common highway pavement markings).

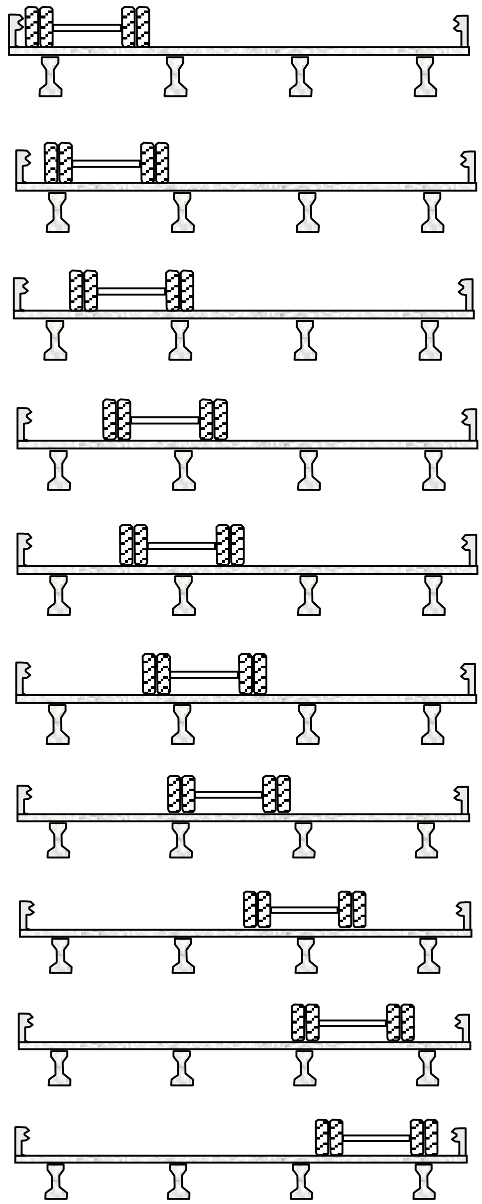

Figure 5: Truck Positions for Slow Speed Tests.

Up to 5 test runs will be conducted at "highway" speeds. Proposed vehicle positions for these tests are shown in Figure 6. The exact speed at which these tests will be done will depend on the characteristics of the test truck and the posted speed limit. Ideally, these tests will be done at speeds that loaded trucks are expected to traverse the bridges once they are placed in service.

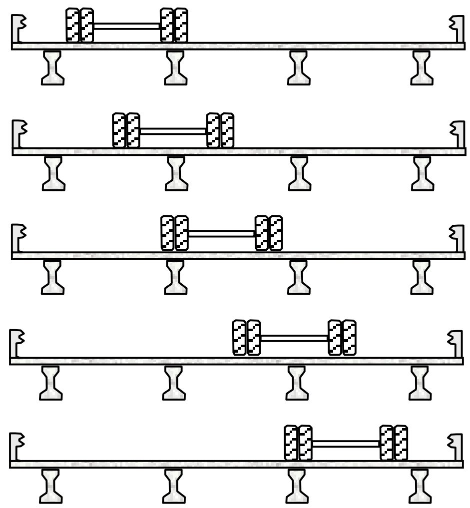

Figure 6: Truck Positions for High Speed Tests.

Two slow speed tests will be conducted on each deck using two vehicles traveling side-by-side across the bridges (see Figure 7). These tests are expected to accomplish two objectives: 1) place the greatest demands on the decks, and 2) provide data on the general linearity of the deck responses by exercising them under two different levels of demand. As mentioned above for the single vehicle tests, these runs will probably be repeated, in the event that the properties of the decks are altered by the load events themselves.

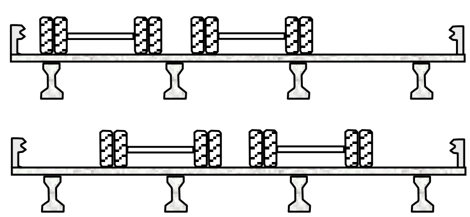

Figure 7: Truck Positions for Slow Live Load Tests Using Two Trucks Side-By-Side.

Action Items for Next Quarter:

- Coordinate live load test preparations with Sletten Construction and MDT
- Conduct live load tests

Task F: Long-Term Monitoring

Monitoring Global Bridge Movements through Surveying

Global bridge movements will be monitored by measuring relative changes in the elevation and the horizontal position of various points on the surface of each deck. Initial measurements will be made when the live load tests are conducted. Elevation measurements will be made at 36 locations on each deck, namely, over the abutments, interior bents, and diaphragms of each bridge at the location of each stringer (28 measurements), and between stringers in the instrumented areas of the decks (8 locations). In the horizontal plane, 14 measurements will be made, namely, over the abutments, interior bents, and diaphragms of each bridge at the location of the exterior stringers. Elevation and position measurements also will be made at two locations on each abutment. Permanent reference points were installed at the west side of the north abutments of each bridge. All measurements will be made with conventional surveying equipment, with the intention of locating each point to the nearest millimeter.

Action Items for Next Quarter:

- Conduct global bridge surveying
- Purchase necessary surveying equipment

Corrosion Testing

Prior to pouring the bridge deck concrete, wire leads were connected to two transverse and two longitudinal bars in each deck for conducting half-cell potential tests. The lead wires exit the concrete on the west side of the bridge decks. Initial half-cell potential readings will be made during the first live load tests. Preparations will also be made for making benchmark chloride ion and carbonation tests.

Action Items for Next Quarter:

- Conduct half-cell potential tests

Crack Mapping

The first scheduled crack mapping exercise (conducted by Craig Abernathy of MDT Research) is scheduled to occur coincident with the live load tests. The results will be provided to WTI for inclusion in the interim project report.

Action Items for Next Quarter:

- Conduct crack mapping

Task G: Analysis

Early data collected from the bridges has been reviewed and some preliminary analyses have been performed. As might be expected, elevated temperatures were observed during curing. Cyclic behavior has been seen in most of the strain gages that obviously correlates with diurnal temperature fluctuations. Figure 8 shows the temperature near the bottom of the three bridge decks as a function of time since they were cast. Variations in the hydration temperatures between the decks are obvious at early times after their construction. The location at which the temperatures were measured is shown in Figure 9 as position F-3. Note that the peak temperature in the HPC deck occurred later than the peaks for the Empirical and Conventional decks. This behavior is most likely attributable to the retardant used in the HPC mix design. Also note that even though the Conventional and Empirical decks utilized the same concrete mix design, their peak temperatures are quite different. Ambient conditions for these two decks during the pour were similar. At this point, there is no certain explanation as to why these differences occurred or if they are truly significant. Temperatures measured at different locations in one deck have been seen to vary by up to ten degrees during curing. Cyclic behavior of the deck temperature is a result of diurnal temperature fluctuations. These affects are more noticeable once the curing cycle was complete. Straight-line portions of the graph correspond to intervals when the data logger was not operating.

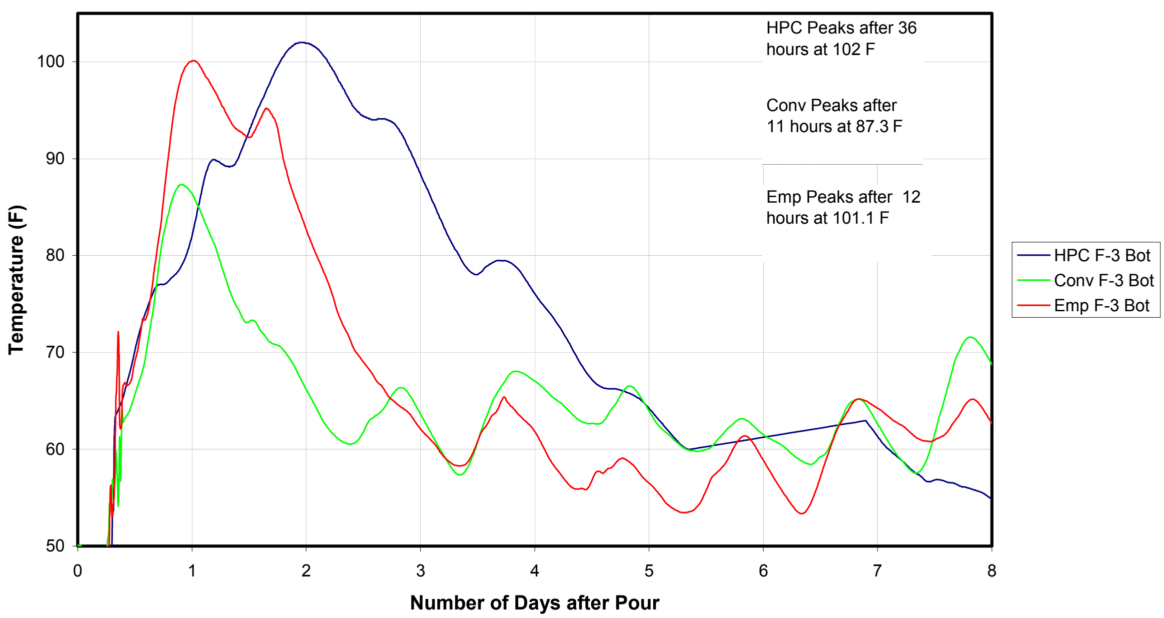

Figure 8: Comparison of Bottom Deck Temperatures During the Cure Cycle.

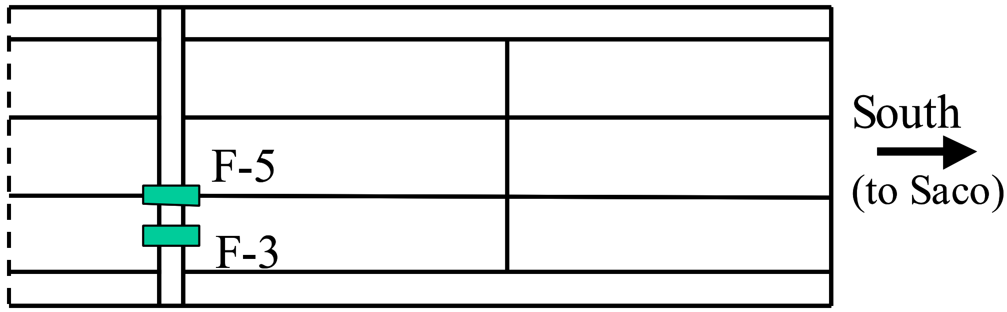

Figure 9: Location of Measurements.

Strain measurements in the bridge deck are made using three technologies: bonded strain gages, strain gages embedded in concrete and vibrating wire strain gages embedded in concrete. A comparison of the output from each of these gages is shown in Figure 10. Values of strain in microstrain (με) are shown on the left axis and temperature (in degrees F) is shown on the right axis. Figure 9 shows the physical location of the strain measurements (position **F-5**). As illustrated in Figure 10, strain gages bonded to the reinforcement and the vibrating wire technologies appear to exhibit similar direction and magnitude of strain. However, the embedded strain generally indicate lower magnitudes. Differences may depend on exactly what each gage is measuring (e.g., concrete strain versus strain on reinforcement). These differences continue to be studied, and future data and analysis will help determine their origin and significance.

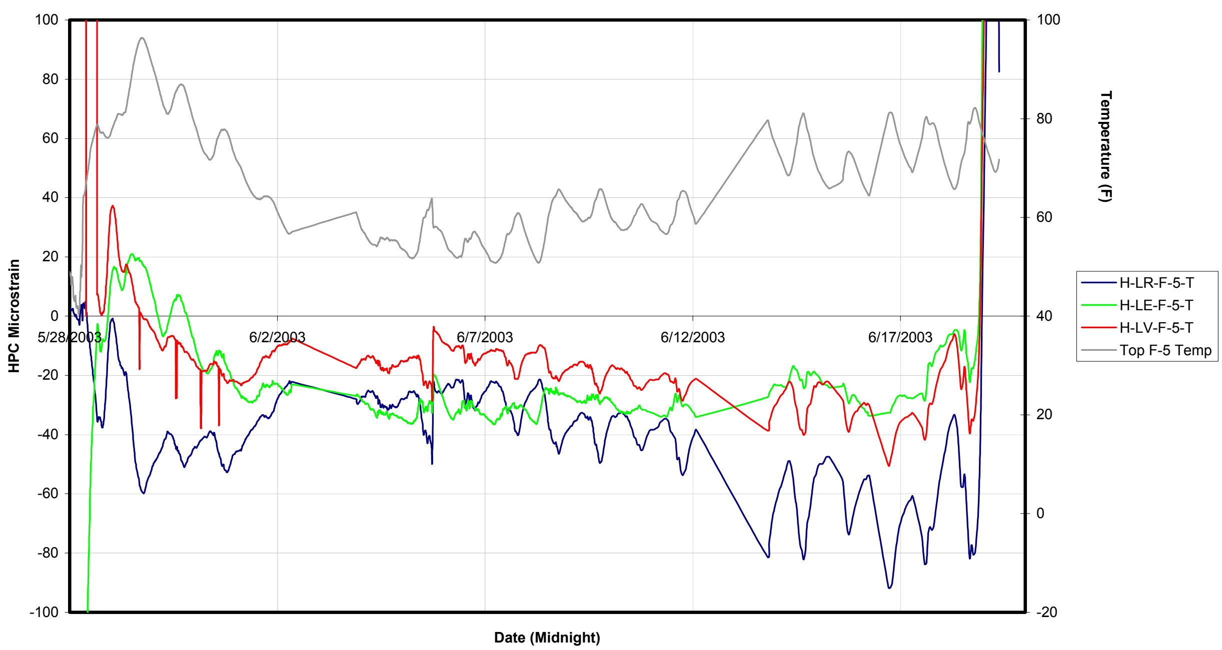

Figure 10: Comparison of Strain Using Different Technologies in the HPC Bridge Deck.

Action Items for Next Quarter:

- Continue analyzing data from each of the bridge decks

Task H: Project Reporting

A draft instrumentation plan has been prepared which includes 1) a complete instrumentation list that indicates the type, location, and expected level of response of each gage, and 2) a thorough description of the specific installation method proposed for each type of gage including the manner in which it will be wired into the data acquisition system. The information contained in this document will be summarized in the interim project report.

Action Items for Next Quarter:

- Quarterly progress report for first quarter for state fiscal year 2004